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Engineering Ethics: The Kansas City Hyatt Walkway Collapse

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Engineering Ethics: Kansas City Hyatt Walkway Collapse

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Prologue

The mood was festive in the huge atrium of the Kansas City Hyatt Regency hotel on a warm summer night in July, 1981. More than 1,500 people were enjoying a weekly dance contest called the "Tea Party" hosted by a local radio station.

Sally Firestone was all dressed up, standing on a catwalk above the atrium floor, watching the dancers below. Suddenly, she heard a loud "crack." Then, her world came crashing down around her. As the band played Duke Ellington's "Satin Doll," catwalks lined with people on the second and fourth floor above the atrium fell onto the dance floor below.

The deadliest structural failure in U.S. history killed 114 people and injured nearly 200 others. Ms. Firestone lay unconscious and trapped for hours under the debris. She was eventually rescued, but was left a quadriplegic.

"I'm not really bitter. I'm just amazed that no one discovered the problems with the building," said Firestone many years later. "So many things happened along the way that should have been caught."

Introduction

As Kansas City Mayor Richard Berkley stood in front of the Hyatt Regency shortly after the accident, he called it a "very serious tragedy." But, what made this disaster even more tragic was that it should never have happened.

The collapse of the skywalks resulted from a simple design error. In 1981, there was nothing particularly complex about designing skywalks that hang from the ceiling, supported by rods. At the time, the engineer of record for the Kansas City Hyatt Regency hotel project had many previous years of experience designing structures. Yet, the design error was so simple that a junior or senior undergraduate engineering student could have recognized it.

And there were numerous opportunities for the design error to be caught during design and construction.

This course will examine the events that led up to and caused the Kansas City Hyatt disaster. We'll see how negligence and lack of design responsibility by the engineer of record was the direct cause of the accident. We'll see how constructability issues led to an ill-fated design change by the fabricator. And we'll learn how the lack of a change management process for shop drawings contributed to the tragedy.

Finally, we'll discuss lessons learned from this accident that you can take forward with you in your professional practice.

Project History

In 1976, Crown Center Redevelopment Corporation initiated a project to design and build a Hyatt Regency Hotel in Kansas City, MO. Gillum-Colaco, Inc. was selected as the consulting structural engineer for the project. Gillum-Colaco subcontracted the structural engineering work for the project to their subsidiary firm, Jack D. Gillum & Associates (G.C.E.).

PBNDML Architects, Planners, Inc. was selected as the architect for the project. Eldridge Construction Company was selected as the general contractor; and they in turn subcontracted the fabrication and erection of the hotel's atrium steel to Havens Steel Company.

The project employed three distinct "teams," each with different roles. The "design team," consisting of PBNDML and G.C.E., was authorized to control the entire project on behalf of the owner. Eldridge Construction Co., acting in the role of the "construction team" was responsible for general contracting. And the "inspection team" was made up of two inspection agencies, H&R Inspection and General Testing, as well as a quality control manager, a construction manager and an investigating engineer.

The proposed Kansas City Hyatt Regency Hotel consisted of three sections: a 40-story tower section, a function block, and a connecting atrium. The atrium, where the accident occurred, is a large open area approximately 117 feet wide x 145 feet long x 50 feet high. Three suspended "skywalks" spanned the atrium at the 2nd, 3rd and 4th floor levels. The 3rd and 4th floor walkways were each suspended from the atrium roof trusses, while the 2nd floor walkway was located directly underneath the 4th floor walkway and was suspended from the 4th floor walkway (see Figure 1 after the collapse showing the dangling 4th floor walkway rods to the right in the picture).

Figure 1 - Third Floor Walkway (left)

As is fairly typical for these types of projects, the architect, PBNDML, prepared the project specifications and G.C.E., the structural engineer, was responsible for producing structural engineering drawings. Havens, the atrium fabrication contractor, used G.C.E.'s structural engineering drawings as the basis to create shop fabrication drawings.

G.C.E.'s Original Design

The Kansas City Hyatt atrium catwalk design prepared by G.C.E. intended for the 2nd floor and 4th floor walkways to be suspended one under the other from six single continuous 1 ¼" diameter round steel rods anchored in the ceiling. The 3rd floor walkway was to be located east of the 2nd and 4th floor walkways and was to be suspended from the atrium ceiling in the same manner.

The box beam members that formed the lateral structural support for each walkway were comprised of two (2) 8 x 8.5 MC channels welded toe-to-toe (see Figure 2a).

On the 2nd and 4th floor walkways, the rods were intended to run from the ceiling down to and through the 4th floor box beams and were then to continue down to and through the 2nd floor box beams, where the rods would terminate with a nut and washer. The ends of the rods were depicted as threaded so that the walkways could be leveled by adjusting the nuts on the threaded rods.

A total of 60 structural design drawings were prepared by G.C.E. and were transmitted to Havens through the normal document transmittal process. The project engineer for G.C.E. had prepared preliminary sketches for the atrium walkways showing design criteria, including calculated preliminary loads and information on the box beam hanger rod connection; however these preliminary sketches were not transmitted to the fabricator along with the structural drawings.

Design Change

From Havens' perspective, there were two problems with G.C.E.'s design. First, the long rods required to hang the 2nd floor catwalk from the atrium ceiling were not readily available. Building the walkways per the G.C.E. design would have resulted in material delays that could have potentially impacted the overall project schedule.

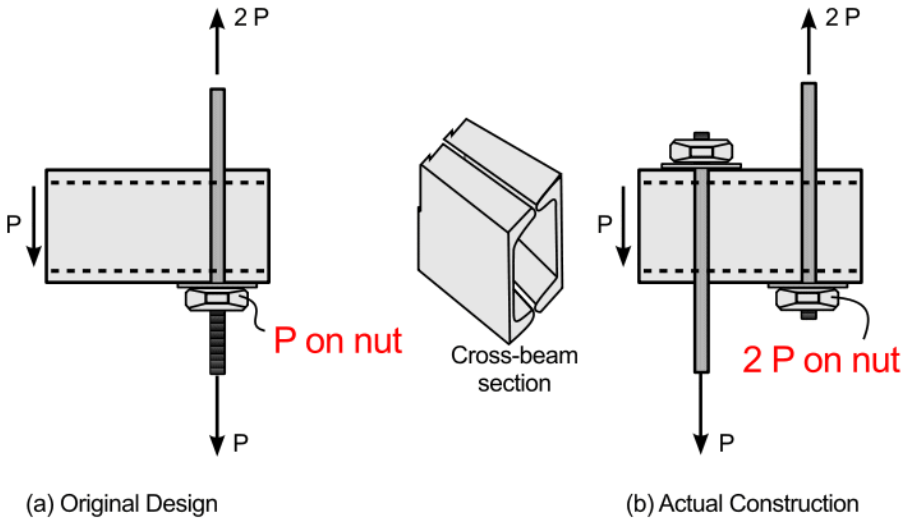

Figure 2 – 4th Floor Atrium Walkway Box Beam Connection Detail

Secondly, the original design would have required threading the entire length of the long rod in order to install a nut under the 4th floor catwalk box beam. The nut for the 4th floor catwalk box beam would have to be installed after inserting the rod through the 2nd floor catwalk box beam, and would likely have required extensive scaffolding to complete the connection. This would have resulted in significantly higher erection costs. Further, Havens was concerned that the threads on the rod might be damaged during the erection process.

Therefore, Havens changed from a single to a double hanger rod box beam connection at the 4th floor catwalk (see Figure 2b). A rod was hung from the ceiling down to the 4th floor walkway. And a second rod was hung from the 4^{th} floor walkway down to support the 2nd floor walkway. This allowed the use of shorter rods, which were readily available. It also simplified the erection process and eliminated the need for the entire rod to be threaded.

Havens claims to have called G.C.E. to "red flag" the connection design change. G.C.E. claims that the call was never made. Regardless of the disputed phone call, the change was reflected on Havens' shop drawings and erection drawings, which were forwarded to G.C.E. On February 26, 1979, G.C.E. returned the drawings to Havens, stamped with the project engineer's engineering review seal, authorizing construction.

Roof Collapse

On October 14, 1979, while the hotel was still under construction, part of the atrium roof collapsed. Fortunately, it was a Sunday, and there was no construction activity occurring at the time, so there were no injuries.

The owner used resources from the project's "inspection team" to investigate the roof collapse. Additionally, the owner hired an independent engineering firm, Seiden-Page, to determine the cause. The investigation determined that the roof collapse occurred due to faulty roof connections. The problem was fixed. However, the owner did not direct or ask Seiden-Page to check the walkway connections or any other structural details on the project.

As a result of the roof collapse, G.C.E. wrote the owner stating that G.C.E. would begin a thorough design check of all steel connections in the design. Construction on the project continued, and the hotel opened for business in July, 1980.

The Accident

On July 17, 1981, just one year after the hotel opened, the load resulting from people standing on the walkways caused one of the connections at the 4th floor walkway to fail. Due to a lack of redundancy in the design, the connection failure resulted in the collapse of the 4th floor walkway onto the 2nd floor walkway, which then collapsed onto the floor below.

The collapse of the walkways fractured water pipes in the atrium, which flooded the hotel's main entrance. Nonetheless, rescue efforts were swift and well coordinated. More than 40 rescue vehicles quickly converged on the scene from all over the Kansas City metropolitan area and

helicopters were used to take the injured to area hospitals. Aiding the rescue efforts were scores of doctors in town for a Radiology convention who happened to be dining in the hotel at the time of the accident.

The accident killed 114 people and injured nearly 200 others, making it the deadliest structural failure in U.S. history.*

> * Note: This claim is debatable since the collapse of the World Trade Center Towers on September 11, 2001 resulted in a much higher death toll. However, most experts do not categorize the WTC collapse as a structural "failure" because the buildings were never intended to be designed for such a terrorist attack. By contrast, the Kansas City building code mandated that the Hyatt walkways be designed for the live load conditions that existed on the night of the collapse.

The Investigation

Speculation about the cause of the accident began before emergency response workers had even finished rescuing survivors and removing bodies from the debris. One early theory was that that the walkways collapsed due to harmonic stress introduced by people dancing on the catwalks, although witnesses dispute whether anyone on the walkways was dancing. Another theory speculated that the fabricator had failed to install washers along with the nuts at the walkway connections.

Figure 3 - Fourth Floor Walkway Box Beam Connection Failure

At the request of Kansas City's Mayor, Richard Berkley, the National Bureau of Standards (NBS) – now the National Institute of Standards and Technology – initiated an investigation of the Kansas City Hyatt Regency Catwalk collapse. The NBS determined that the load at the bottom nut on the rod running from the 4th floor walkway to the ceiling had deformed the C-channels in the box beam. The weld joint between the two facing C-channels then split and the washer, nut and rod slipped through the box beam, resulting in the collapse of the walkway (see Figure 3).

Because of the double rod design change initiated by Havens, the load at the nut on the 4th floor upper rod section was twice the load of the original single rod design. The investigation discovered that the original design could only support 60% of the load required by the building code. The shop drawing change to a two rod design doubled the load at the 4th floor connection, meaning that the as-constructed connection could only bear 30% of the mandated load.

Responsibility for Designing Connections

The steel-to-steel connection is what ultimately failed and resulted in the accident. Therefore, a historical perspective of design responsibility for steel-to-steel connections is in order. Prior to World War II, the standard connections for steel columns and beams in buildings were rivets.

Engineers had complete control over the design of all structural members in a building, including rivets.

As different bolted connections became prevalent in the post-war era, steel fabricators developed preferred methods of fabricating connections based upon their preferred fabrication and erection techniques. Fabricators found that connections designed by the engineer did not always match their preferences, which sometimes put the fabricator at a competitive disadvantage.

To save time and money, some fabricators began asking engineers for authority to design the connection details to suit the fabricator's preferences. The engineers did not object to giving the fabricators this authority, provided that the connections were structurally sound. As this practice became established, some fabricators became proficient at designing simple connection details, usually with the aid of the AISC Manual of Steel Construction.

The specifications used on the Kansas City Hyatt Regency project did not specifically direct the fabricator to design steel-to-steel connections. It is ultimately the structural engineer's choice as to who will design which connections. Over the years, the practice had become that the engineer would communicate whether he wished the fabricator to design a connection by the level of detail that he provided on the structural drawings. Where a fabricator sees a "complete" connection design on the drawings, then he is to copy it onto his shop drawings. Where a connection detail is omitted or is "incomplete" on the structural drawings, it is understood, by custom and practice, that the fabricator will design the connection and indicate such design on his shop drawings.

For "simple" connections, the fabricator can easily design the connection based on guidance from the AISC manual. For "special" connections which the engineer wishes the fabricator to design, the engineer must provide on the structural drawings all necessary information on loads, stress and eccentricities. Although special connections are typically designed by the structural engineer, he may elect to delegate this design work to the fabricator, provided that sufficient detail is provided on the structural drawings to allow the fabricator to design the connection.

In the case of the Hyatt atrium walkways, the original box beam connection detail shown in G.C.E.'s structural drawings was a "special" connection. It was not a "standard" connection that could be designed by reference to uniform load tables in the AISC manual because there is a concentrated load applied near the end of the box beam, thus creating a structural eccentricity. Further, the connection was "special" because it was non-redundant. The failure of any of the box beam connections would have led to collapse of the entire walkway structure.

Given that the connection was "special" as it was depicted on the structural drawings, the engineer (being the only party with the knowledge of the information and the assumptions associated with the design of the "special" connection) had an obligation to either complete the design of the connection himself or direct the fabricator to use stiffeners or bearing plate(s) in the design of the connection.

Missouri Board of Architects, Professional Engineers and Land Surveyors Investigation

The Missouri Board of Architects, Professional Engineers, and Land Surveyors charged and ultimately convicted the engineer of record and the project engineer, both employed by G.C.E., with gross negligence, misconduct, and unprofessional conduct in the practice of engineering. Both engineers lost their P.E. licenses in Missouri.

At the Board's hearing, the G.C.E. engineers claimed that they thought it was Havens' responsibility to design and check the walkway connection details. They made this claim in spite the fact that the engineer of record stamped Havens' shop drawings and erection drawings with his professional seal.

Ultimately, the Board determined that it was, in fact, the responsibility of the project engineer and the engineer of record to ensure that the connection details were structurally sound. The Board concluded that the failure to check the load capacity of a crucial hanger even once showed a complete disregard for the public welfare.

Factors That Contributed to the Collapse

In the end, the cause of the Hyatt walkway collapse was overstress of the connection detail designed by Havens, which could only withstand 30% of the load required by code. However, as is the case in many accidents, in the Hyatt project there was a chain of errors and missed opportunities to correct these errors. It was not just one simple mistake that ultimately led to the tragedy.

First, the original G.C.E. design was inadequate. In addition to the fact that the original design could only withstand 60% of the load required by code, constructability was not adequately considered in the design. The original single rod design was not practical from an erection standpoint, which was the catalyst for Havens to modify the design in the first place. And, the original G.C.E. design had no redundancy.

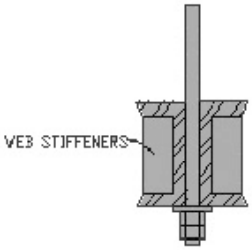

Figure 4

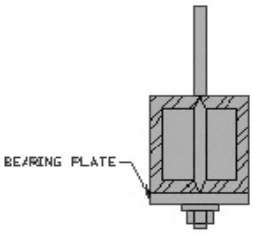

Figure 5

Additionally, the toe-to-toe channels in the box beam design resulted in a weak welded joint, which allowed the nut to pull through the box beam assembly. A back-to-back channel design using web stiffeners (Figure 4) or a toe-to-toe design with bearing plates (Figure 5) would have made the connection much more robust.

The building code process also failed the public. Neither the original design, nor the as-built connections met the building code requirements. However, due primarily to understaffing, the city's building inspectors did not discover the design errors and the building was certified as safe for occupancy in 1980. At the time, Kansas City's Codes Administration Division was not required to review design changes over the course of a project. And structural calculations were rarely reviewed by City Engineers. Finally, the building code should have required redundancy in the design of such a critical structural component.

G.C.E. had ample opportunity to discover the error when checking Havens' shop drawings and erection drawings. The fact that G.C.E.'s engineer of record on the project stamped the drawings should have served as a reminder of his obligation to check the drawings. Further, the connection detailer, architect, fabricator, and technician all testified that they had contacted the project engineer regarding the structural integrity of the connection detail. Each time he assured them that the connection was structurally sound.

Finally, the collapse of the atrium roof during construction of the hotel should have been a wake-up call for the owner, the project engineer and the inspection team. The failure of the roof connections should have alerted the team to the need to check connection details in other components of the project. The owner did hire an independent consultant to investigate, but his scope of work was limited to investigation of the roof collapse. It is assumed that the consultant was not asked to investigate other structural connections because of the cost that would be involved.

Lessons Learned

Despite the injuries and loss of life, some good came out of the terrible tragedy at the Kansas City Hyatt. Changes were made in the Kansas City Codes Administration Division and in other city code inspection departments across the country. And the American Society of Civil Engineers (ASCE) announced a policy of holding structural engineers responsible for all aspects of structural safety in their building designs. Thus, there should be no confusion about the structural engineer's obligation to review shop drawings and erection drawings.

As engineers, we can learn valuable lessons from the tragedy as well:

1. Do Sweat the Details – In a 40-story hotel project, the connection detail for a walkway may have seemed to be a minor detail. But, an error in this small detail resulted in the deaths of 114 people. Pay attention to the details! Check and recheck your work. Follow all applicable codes and regulations. You should always be diligent in your work, particularly in matters that affect the safety and health of the public.

2. Don't Emphasize Cost/Schedule to the Detriment of Safety – Havens Construction changed to the ill-fated double rod connection detail because of cost and schedule considerations. The hotel limited the scope of the roof collapse investigation, presumably to save money. And, many believe that building inspectors missed the design error due to understaffing. Finally, we can only speculate, but it's quite possible that the project engineer did not check his work because of competing work priorities. Many engineers find themselves under pressure to produce more,

with less people, and a shorter schedule. Don't fall into the trap of sacrificing quality and safety for cost or schedule.

3. Consider Constructability in Your Design – Constructability issues don't normally cause a chain of events leading to the sort of death and destruction seen at the Kansas City Hyatt. But, a design that's not practical to build will invariably result in cost and/or schedule impacts. During the design phase of the project, consider how difficult your product will be to fabricate and erect. Ask your fabricator about his preferred fabrication methods and make sure you consider the fabricator's erection sequence and methods in your design.

4. Change Management – It's not clear whether a formal change management process would have averted the tragedy at the Kansas City Hyatt. Nonetheless, it is imperative that you use a change management process on your projects. Changes initiated by anyone on the project should be documented in writing through a formal process. And any modifications to design details initiated by the fabricator should require written approval from the engineer of record.

5. Design Responsibility – ASCE guidelines issued as a result of the Kansas City Hyatt accident make it clear that the project structural engineer is responsible for all aspects of a building's structural design. Regardless of the type of project, it is prudent to clearly delineate responsibilities between parties at the beginning of the project. This can be accomplished using a number of different tools, such as a Project Responsibility Matrix and clear and thorough job descriptions for each position on the project.

Fundamental Canon #1 of the NSPE Code of Ethics states:

"Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties."

The Kansas City Hyatt walkway collapse serves as a horrible reminder of the potential consequences when we are not diligent in our duties.